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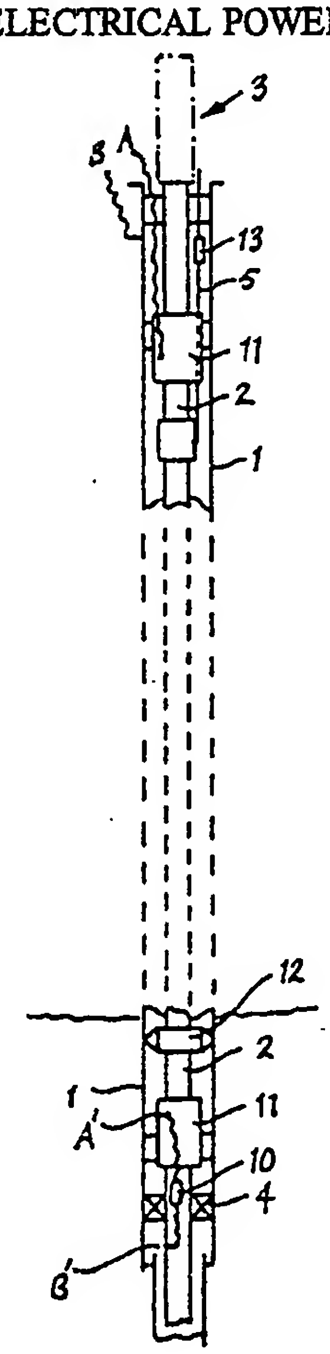
(54) Title: IMPROVEMENTS IN AND RELATING TO ELECTRICAL POWER TRANSMISSION IN FLUID WELLS

(57) Abstract

A method of, and apparatus for transmitting electrical power along the borehole of an oil or gas well being drilled or in production. The invention has particular application in downhole monitoring, an electrical sensor (10) for the particular parameter feeding its output signals to A', B' and via, respectively, an insulated central section of the tubing string (2) and the casing (1) these signals being withdrawn at A, B for suitable monitoring. An isolating sub (11) for electrically insulating the central section of the string is disclosed.



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Improvements in and relating to electrical power transmission in fluid wells.

TECHNICAL FIELD OF INVENTION

This invention relates to the passage of electrical power along the tubing string of a borehole which has particular reference to the downhole monitoring of some parameter (e.g. pressure, temperature or fluid velocity) relevant to the production of a borehold for a fluid well or the extraction of fluid (e.g. oil or gas) from such a borehole after its production. The invention also extends to a borehole per se adapted for such passage of electrical power.

BACKGROUND ART

It has long been appreciated that considerable economies in the control of drilling of a borehole or the extraction of fluid from a borehole, result from accurate downhole monitoring of suitable parameters. Thus for example, the extraction of oil from an oil well can be optimised (with a substantial increase in potential yield from a well), if the changes in pressure occurring at the bottom of the well can be accurately charted. Heretofore there has been no wholly reliable method of monitoring the downhole pressure without interrupting the flow of oil from the well. Accurate pressure sensing devices are available which will operate satisfactorily in the conditions existing at the bottom of the borehole, but the problem has been the telemetering of the information generated by the sensing device several thousand feet down in the earth to the wellhead where the appropriate control action has to be taken. It has been proposed to transmit the sensed information up to the surface using an electrical cable clipped to the outside of the tubing string or incorporated in the walls of the pipes making up the string, but neither of these possibilities has met with much success. A separate electrical cable is susceptible to damage and difficulties arise in correctly connecting together the adjacent ends of cable which have been incorporated in the walls of the pipes interconnected to make the tubing string. Because of the difficulties experienced with the prior art arrangements it has been the practice, to ensure good well management, to periodically stop the oil or gas flow for a few days every few weeks, and to make the

necessary measurements during the interruption in flow, a special sensor being lowered down the string for measurement purposes. Naturally, however, any interruption in flow from a production well represents a substantial loss of revenue to the oil company and is highly undesirable.

Similar considerations apply to the downhole monitoring of critical parameters in the actual drilling of the borehole so that an improved method of power transmission along a borehole which would permit reliable downhole monitoring has useful applications in both activities.

THE INVENTION

In its broadest aspect the invention relates to a method of transmitting electrical power along a borehole comprising an electrically-conducting string located within an electrically-conducting casing which is characterised in that a section of the tubing string between a wellhead hanger and a downhole packer is electrically insulated from upper and lower tube ends by means of electrically isolating subs and from the surrounding casing by electrically insulating centralisers and in that power is passed along the borehole using the casing as one conducting link and the said section as the other conducting link.

For downhole monitoring an electrical sensor producing an electrical output related to a parameter sensed down the hole has its output connected between the lower end of said section and the lower tube and the output from the sensor is monitored at the wellhead by connections between the upper end of said section and an upper part of the casing.

The sensor can be of a kind powered by a low voltage dc and this can be fed down the said section from the wellhead or generated in situ using a turbine generator (powered by mud, oil or gas).

The insulating centralisers are employed to prevent short-circuiting between the said section and the surrounding casing and insulating tube centralisers are preferred which are clamped at intervals around the tubing string and bear on the internal surface of the casing. Crude oil or diesel oil can be located in the annular volume between the tubing string

and the casing.

The invention finds particular utility in a downhole pressure monitoring system (using a pressure-sensing oscillator unit whose output frequency is related to the subsisting pressure), but the method of the invention can be used for example for measuring temperature, electrical conductivity, radioactivity, flow velocity, the presence of specified chemicals and indeed any useful parameter for which a suitable sensor can be found.

To ensure good electrical connection at the pipe joints in the string,the pipe lengths may be torqued together to such a degree that cold welding occurs at each joint. A conducting paste (e.g. incorporating a silver or graphite powder) can be used at the joints if required.

The invention also embraces the special equipment needed to isolate a major section of the tubing string from its ends and from the casing and thus extends to the isolating subs, an insulating collar for the tubing string and an insulating coupling for the DHSV control line.

Thus according to a further aspect of the invention a borehole comprising an electrically conducting casing defining the outer extremity of the borehole, and an electrically conducting tubing string extending substantially concentrically through the casing between upper and lower regions thereof,.is characterised in that the tubing string has a central section which is electrically isolated from the said upper and lower regions by a pair of subs and from the surrounding casing by a plurality of spaced-apart electrically insulating centralisers, each sub comprising first and second aligned tube lengths, each of which lengths terminates at its axially outer end in a screw-threaded section and at its axially inner end in an annular face which confronts the annular face of the other tube length, a first electrically insulating ring disposed between said annular faces to space the tube lengths apart and a locking collar having a shoulder confronting a shoulder on said first tube length and a screw-threaded portion engaged in threads on the second tube length, a second electrically insulating ring to space the shoulders apart and

an insulating sleeve to space the locking collar from the first tube length, the locking collar being tightened on the second tube length to compress the two insulating rings and rigidly clamp the tube lengths together, a transmitter and a receiver of electrical power disposed at opposite ends of the said central section, each connected electrically between the casing and the locking collar of the adjacent sub, whereby the electrical circuit between said transmitter and receiver includes the casing and the said central section.

Suitably each sub is constructed to withstand a tension applied between the tapered threaded sections of the outer ends of the tube lengths of at least 180000 Kgs.

Suitably the locking collar includes a cable terminal to ensure low ohmic contact to the second tube length.

Conveniently the interior of the tube lengths are coated with electrically insulating material to increase the length of any shorting path available between opposite ends of the sub through the medium of the liquid flowing through the tube lengths in use of the sub.

Each insulating centraliser can be a ring of electrically insulating material (e.g. PTFE or fibre-reinforced resin) clamped around the outside of the tubing string by metallic ring shackles which include narrow bearings for engaging the casing over localised regions spaced-apart around the periphery of the inner wall of the casing.

Where the DHSV is controlled by a hydraulic control line, the isolator need only provide an electrical break while maintaining a seal capable of withstanding the operating pressure of the valve and a variety of simple connections are available for this.

BRIEF DESCRIPTION OF DRAWINGS

The invention will now be more fully described, by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a schematic representation of a borehole in accordance with the invention and adapted for downhole monitoring in accordance with the method of the invention,

Figures 2 and 7 show parts of the subs used in the well of Figure 1 in greater detail,

Figure 3 is an end view of the sub shown in Figure 2,

Figure 4 is a sectional view of the insulating coupling in the wellhead of Figure 1 in the control line of the DHSV,

Figure 5 is an end view of a tube centraliser used in the well of Figure 1, and

Figure 6 is a sectional view of the centraliser of Figure 5 taken on the line VI-VI.

SPECIFIC DESCRIPTION

Figure 1 represents schematically a production oil well, the casing being indicated at 1, the tubing string at 2, the wellhead tubing hanger at 3 and the downhole packer at 4. In conventional manner a DHSV is located near the upper end of the string 2 and the control line for this is shown at 5. In a typical well the casing 1 would have a diameter of about 25 cms and the string 2 a diameter of around 11cms. The dotted region of Figure 1 could be several thousands of metres in length.

In Figure 1, 10 represents a known type of pressure-sensitive oscillator (e.g. a Hewlett-Packard HP 28118) which generates an ac output (pulsed) when fed with a low voltage dc input, the frequency of the ac output being related to the pressure to which the oscillator is subjected. In a typical case, the oscillator could measure pressures between 70 to 850 bars and over that range the output would range between 500 Hertz and 15000 Hertz. The oscillator 10 is to be used for continually monitoring the pressure in the oil in the vicinity of the packer 4, so that there is a need to supply it with a low voltage dc current (e.g. 24 volts at 30 mA) and to receive from it the pulsed ac in such wise that the frequency of the ac output can be determined reliably at the wellhead. In accordance with the invention this is achieved by electrically insulating the major portion of the string 2 by means of electrically isolating subs 11 from the wellhead hanger 3 and the packer 4 and, by means of insulating centralisers 12, from the casing 1. To prevent the control line 5 shorting out the insulated string section, a control line iso-

lator 13 is employed.

With the major part of the string 2 isolated from the casing 1 and the hanger 3, a dc voltage applied between the points A and B in Figure 1 will appear across the oscillator 10 (to energise the same) and the output from the oscillator 10 will be fed to the points A' and B' at the bottom of the borehole and will appear as an ac signal at A and B. Thus the string 2 and the casing 1 serve as electrical transmission lines for the powering of the downhole sensor and for the transmission of output signals from the sensor to the wellhead.

The isolating subs 11 can each have the form shown in Figures 2 and 3, the sub being oriented so that the arrow X points upwards if the sub is used at the wellhead and so it points downwards if the sub is used at the downhole end of the string 2. It is convenient to use a similar design of sub at each end of the isolated section of the string, although the strength requirement of the lower sub is much less than that of the upper sub.

Referring to Figures 2 and 3, it will be seen that the sub comprises a first tube length 14 and a second tube length 15 which are locked together by a locking collar 16. The outer ends of the lengths 14 and 15 are provided with conventional tapered threads 17 (only shown for the first tube length) to enable the sub to be joined into the string by normal oilwell techniques. The confronting annular faces 14a and 15a of the tube lengths are spaced apart by a first insulating ring 18 located in recesses formed in the faces 14a and 15a. Annular seals 18a (e.g. Wills rings) ensure a liquid tight joint in the vicinity of the ring 18. To provide the clamping force on the ring 18, the locking collar 16 is threaded to the length 15 at 19 and has a shoulder 20 which compresses a second insulating ring 21 against a shoulder 22 of the first length 14. An insulating sleeve 23 ensures that the locking collar 16 does not make any electrical contact with the tube length 13. The locking collar is tightened in place by means of four radial grooves 24 (see Figure 3) and carries an annular bushing 25 of electrically insulating material to space it from the casing 1 (shown by chain lines in Figure 2).

The electrical connection (A in Figure 1) to the isolated section of the string (of which length 15 is a part) is made via the cable 26 shown in Figure 2.

Grooves 27 in the bushing 25 allow the control line 5 to pass within the casing to the DHSV.

The lower sub 11 is inverted with respect to the upper sub and thus serves to electrically isolate the central part of the string 2 from the lowermost part which is in electrical contact with the packer 4, and, via the packer 4, with the casing 1. Figure 7 shows one way of mounting the sensor 10. A recess 30 can be formed in the wall of the tube length 14 and the cable 26 can connect directly to one input terminal and one output terminal of the sensor 10. The connection 31 shown in Figure 7 allows the cable 26 to pass into the recess 30 in a pressure-tight manner without making electrical contact with the tube length 14. The casing of the sensor 10 is electrically connected to the tube length 14 (via the clamping rings 32) and this electrically connects the other input terminal and the other output terminal to the bottom end of the string 2, and via the packer 4, to the casing 1.

To ensure the complete electrical isolation of the central part of the string 2 from the casing 1, the annular centralisers shown in Figures 5 and 6 are employed. One pipe of the string 2 is shown at 40 in Figures 5 and 6 and this is spaced from the casing 1 by a metal ring shackle 41 clamped around an insulating sleeve 42. Both the sleeve 42 and the shackle 41 are in two parts for easy application around a pipe as the string is being formed at the wellhead. As can be seen from the drawings, the shackle is provided with four equally spaced ears 41a, which bear on the casing 1 to centralise the string 2 and prevent electrical contact between the two. The annular volume 43 is filled with an electrically insulating liquid (e.g. diesel oil) during use to ensure that a high ohmic resistance is maintained between the string and the casing, during operation of the monitoring method of the invention. Since any pockets of water in the annular volume would dramatically reduce the ohmic resistance (particularly if they were saline and bridged across between the string and the casing)

it may be desirable to include an emulsifying agent in the oil to ensure that any water present is held as a water-in-oil emulsion.

Although silicon nitride has been mentioned as a material suitable for the construction of the rings 18 and 21 and the sleeve 23, it should be realised that other materials (in particular other sintered ceramic materials) can be used provided they have the necessary strength and insulating properties.

Figure 4 shows the insulating coupling 13 in the control line 5. From the drawing it can be seen that the insulating rings 13a and 13b prevent electrical connection between the inlet pipe and the remainder of the coupling.

The ac pulses appearing between points "A" and "B" at the wellhead can be taken off by conventional connections and leads to suitable monitoring equipment either in the vicinity of the wellhead (e.g. on an offshore platform) or telemetered to a remote location. The equipment used for the processing of the information received from the sensor 10 can be conventional and apart from mentioning the possible need of an amplifying stage across the points "A", "B" (the output signals can be seriously attenuated in their passage to the wellhead) will not be further commented on here.

As previously mentioned, the provision of the insulated section in the tubing string enables electrical power to be fed to downhole equipment from the wellhead and this represents a further advantage in practice.

CLAIMS

1. A method of transmitting electrical power along a borehole comprising an electrically-conducting string located within an electrically-conducting casing, characterised in that a section of the tubing string (2) between a wellhead hanger (3) and a downhole packer (4) is electrically insulated from upper and lower tube ends by means of electrically isolating subs (11) and from the surrounding casing by electrically insulating centralisers (12) and in that power is passed along the borehole using the casing as one conducting link and the said section as the other conducting link.

2. A method as claimed in claim 1, for downhole monitoring, characterised in that an electrical sensor (10) producing an electrical output related to a parameter sensed down the hole has its output connected between the lower end of said section and the lower tube end and the output from the sensor is monitored at the wellhead by connections between the upper end of said section and an upper part of the casing.

3. A method as claimed in claim 2, characterised in that the sensor output varies in frequency with change in parameter magnitude.

4. A method as claimed in claim 2, characterised in that the centralisers are sleeves clamped around the said section of the tubing string at spaced-apart intervals therealong.

5. A borehole in which the method of claim 1 can be employed, said borehole comprising an electrically conducting casing defining the outer extremity of the borehole and an electrically conducting tubing string extending substantially concentrically through the casing between upper and lower regions thereof, characterised in that the tubing string (2) has a central section which is electrically isolated from the said upper and lower regions by a pair of subs (11)and from the surrounding casing (1) by a plurality of spaced-apart electrically insulating centralisers (12), each sub (11) comprising first (14) and second (15) aligned tube lengths, each of which lengths terminates at its axially outer end in a screw-threaded section and at its axially inner end in an annular face (14a,15a) which

confronts the annular face of the other tube length, a first electrically insulating ring (18) disposed between said annular faces to space the tube lengths apart and a locking collar (16) having a shoulder (20) confronting a shoulder (22) on the first tube length and a screw-threaded portion (19) engaged in threads on the second tube length, a second electrically insulating ring (21) to space the shoulders apart and an insulating sleeve (23) to space the locking collar from the first tube length, the locking collar being tightened on the second tube length to compress the two insulating rings and rigidly clamp the tube lengths together, a transmitter (10) and a receiver of electrical power disposed at opposite ends of said central section, each connected electrically between the casing and the locking collar of the adjacent sub, whereby the electrical circuit between said transmitter and receiver includes the casing and the said central section.

6. A borehole as claimed in claim 5, characterised in that each sub is constructed to withstand a tension applied between the tapered threaded sections of the outer ends of the tube lengths of at least 180000 Kgs.

7. A borehole as claimed in claim 5, in which the locking collar on each sub includes a cable terminal (26) to provide a low ohmic contact to the second tube length.

8. A borehole as claimed in claim 6, in which the interior of the tube lengths of each sub are coated with electrically insulating material.

9. A borehole as claimed in claim 6, in which each centraliser is a ring of electrically insulating material clamped around the outside of the tubing string by shackles (41) which include narrow bearings (41a) engaging the casing over localised regions.

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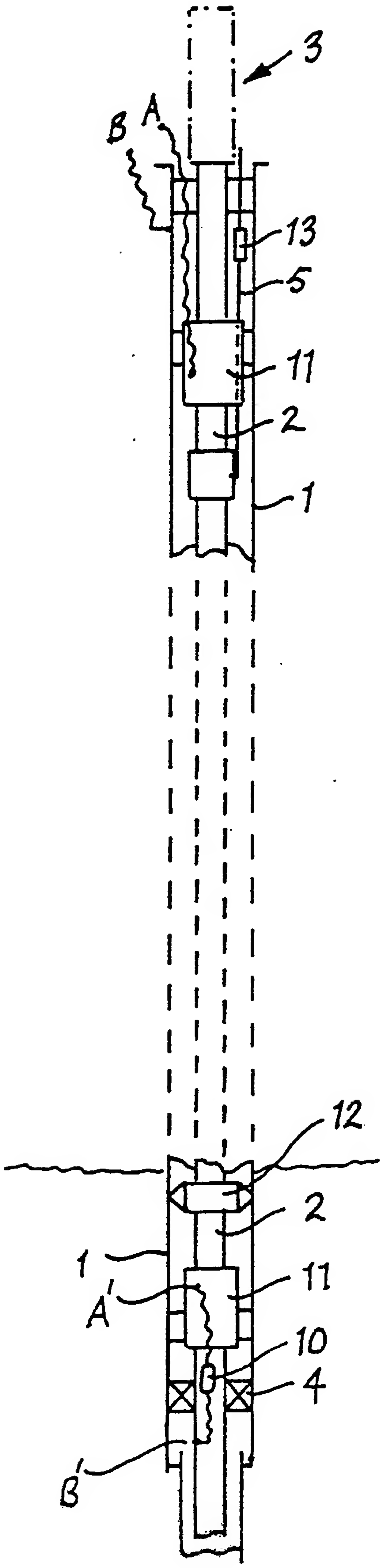

FIG.1

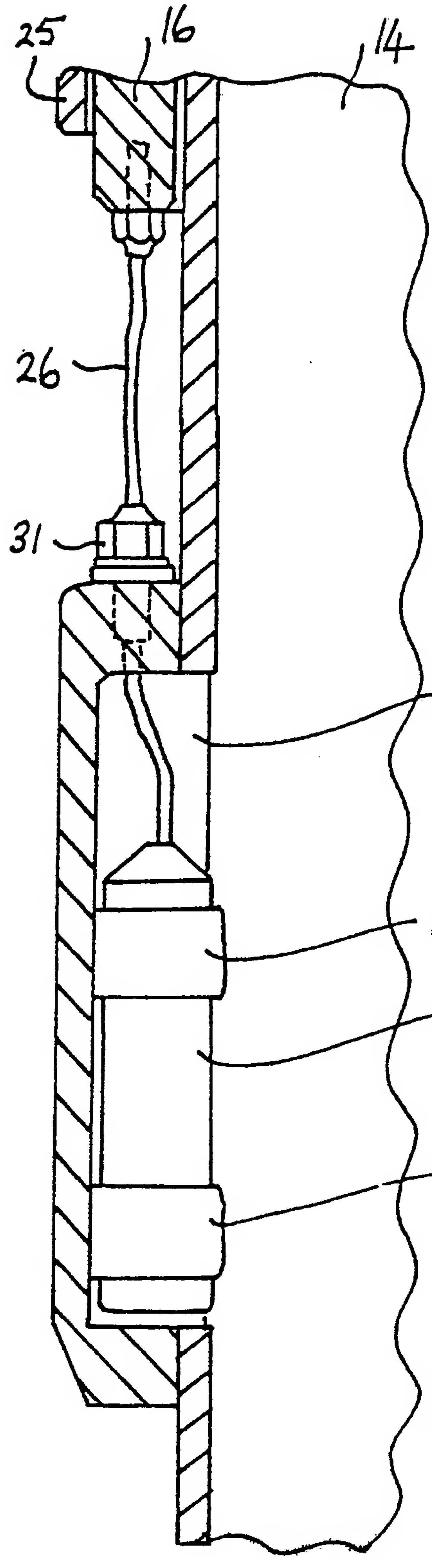

FIG. 7

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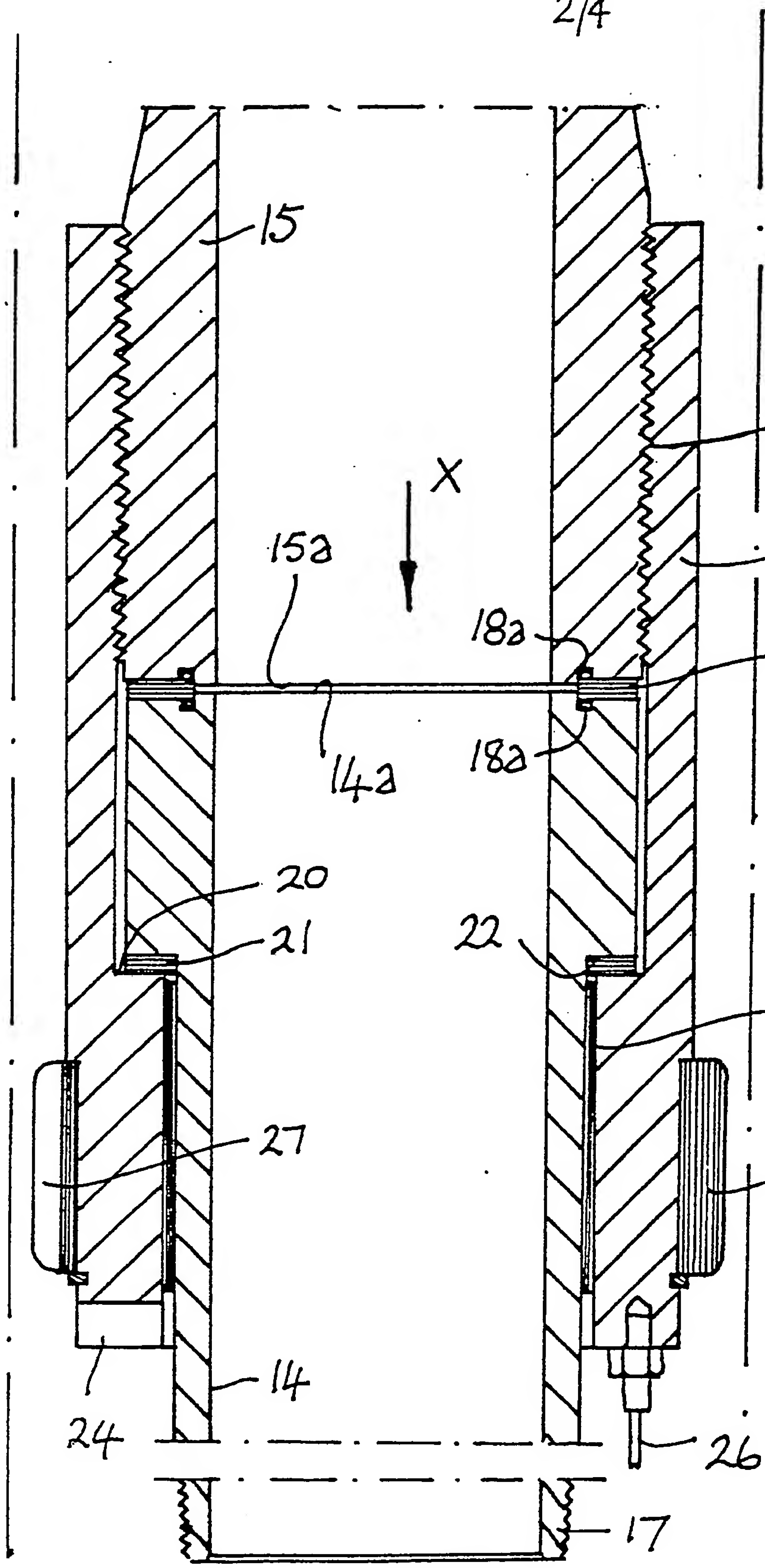

FIG. 2.

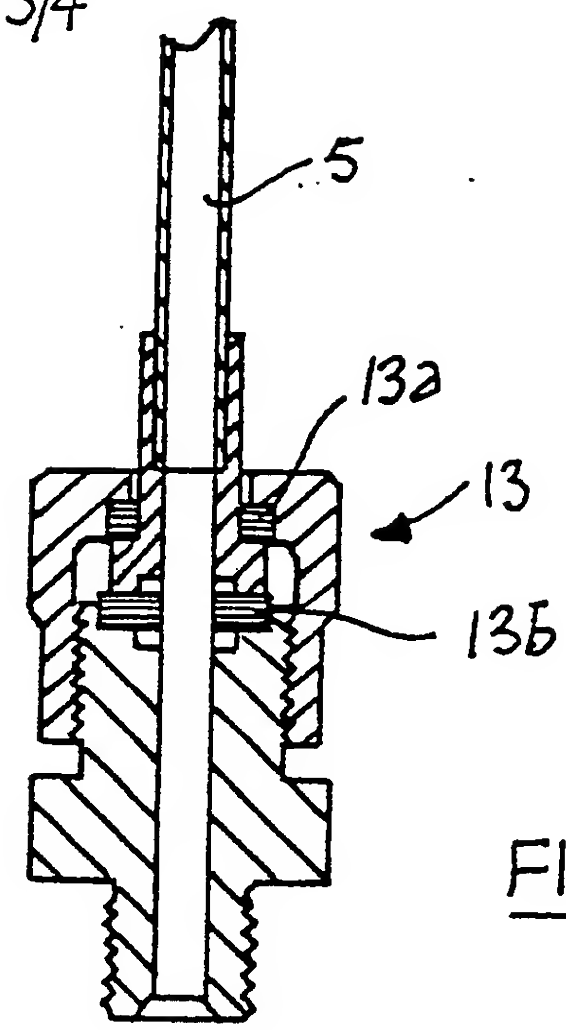

FIG. 4.

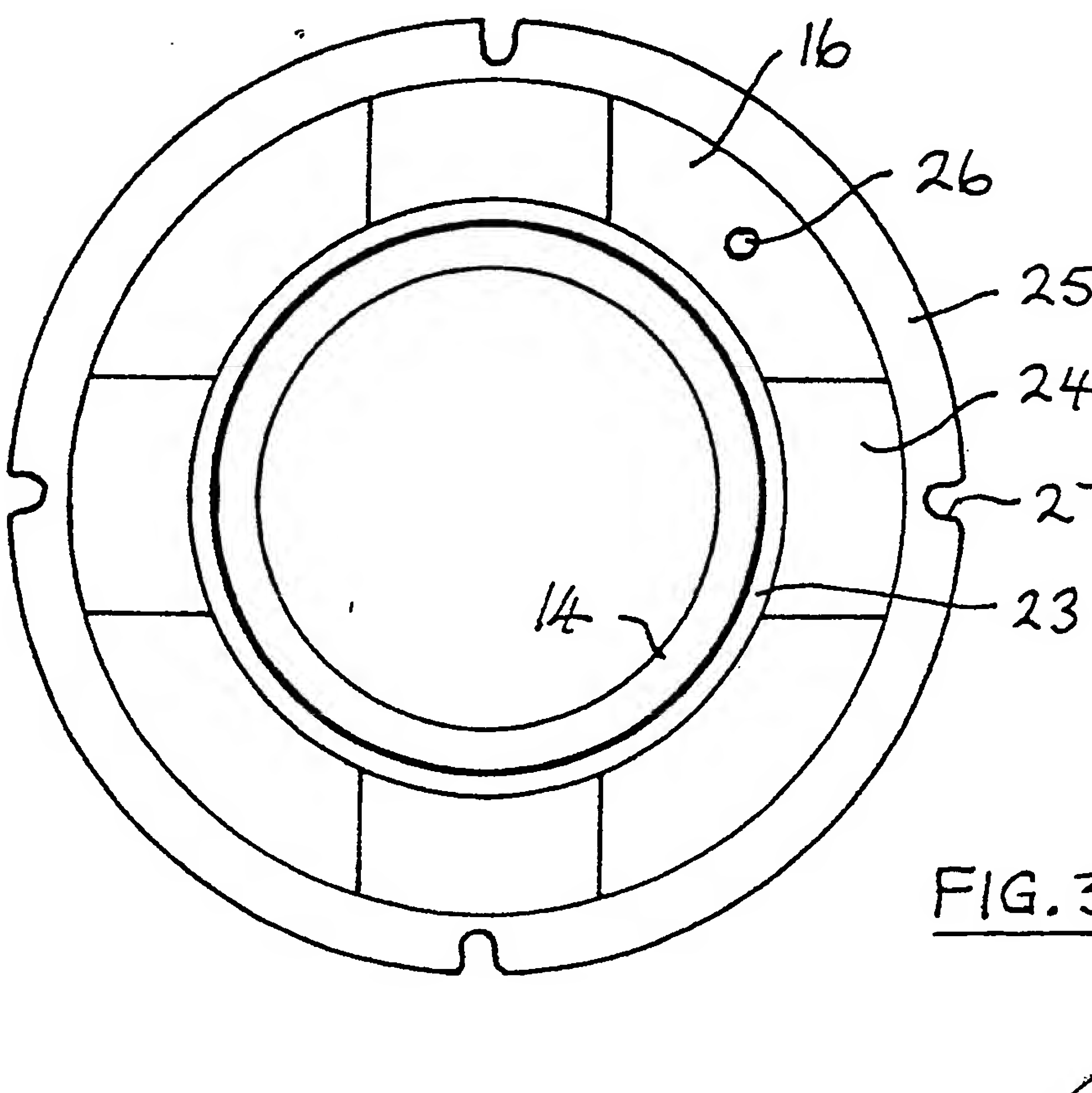

FIG. 3

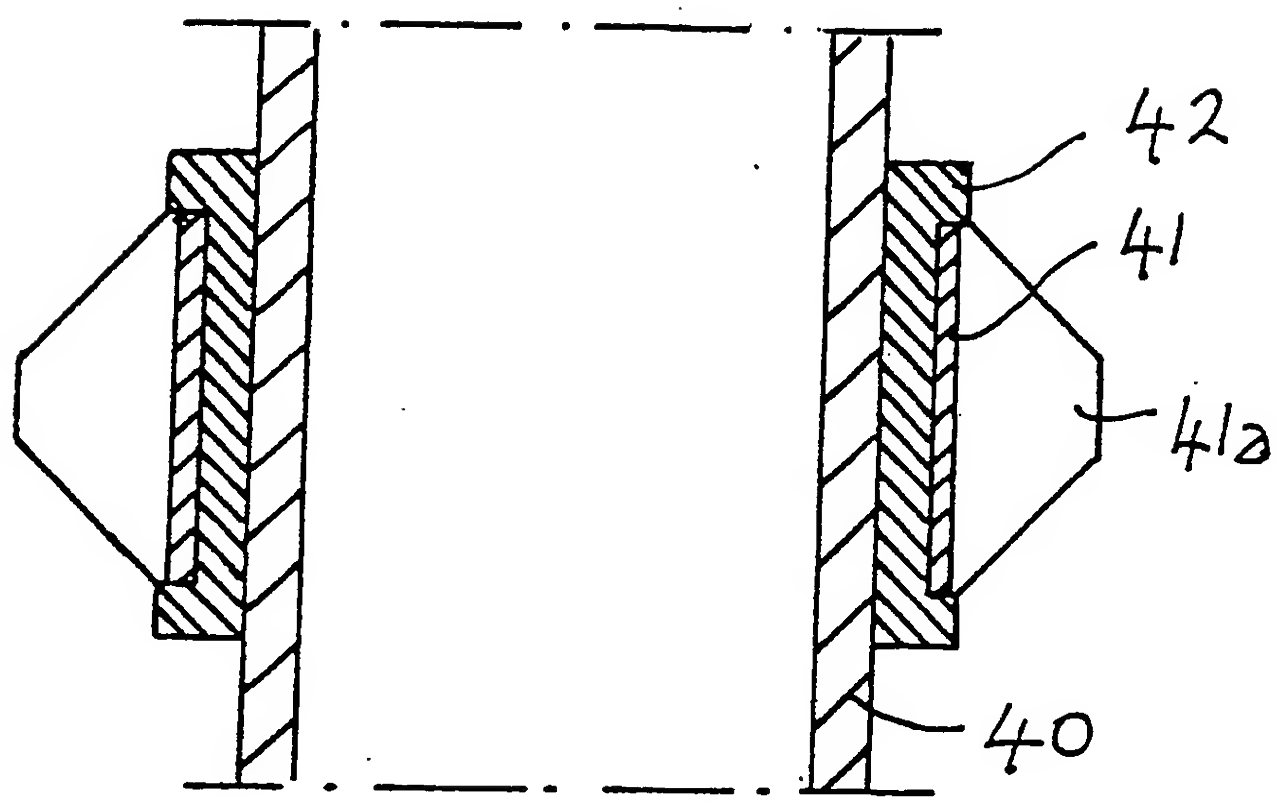

FIG. 6

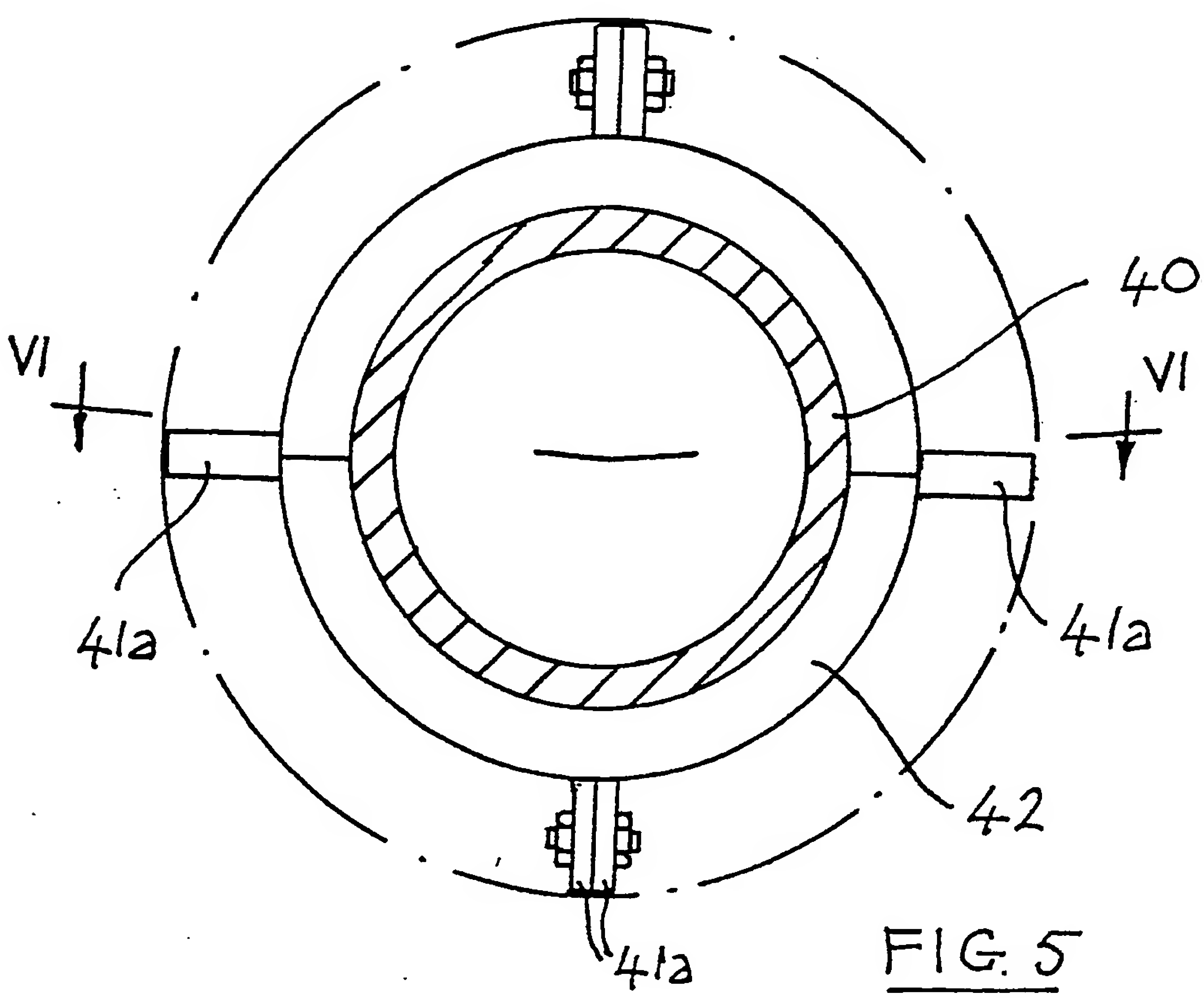

FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 79/00158

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl.^{3} E 21 B 47/12; E 21 B 17/00

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
Int.Cl.^{3}	E 21 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US, A, 2667626, published 26th January 1954, see figure 5; column 11, line 69 to column 12, line 20; column 12, lines 21-24; column 12, lines 5-9, Blancher --	1,2,3,4,5,9
X	GB, A, 1065834, published 19th April 1967, see page 2, lines 81-89; figure 3, Grachey --	1,5,8
X	US, A, 2400170, published 14th May 1946, see page 2, left-hand column, lines 36-43, Silverman --	1,5
	US, A, 4066995, published 3rd January 1978, see column 2, lines 47-49 and 62-65, Matthews --	1,5,8
	US, A, 2941784, published 21st June 1960, see claim 1, Martin --	1,5
	US, A, 2925251, published 6th February 1960, see figure 3; column 5, lines 21-28, Arps --	1,5,6,8
	US, A, 3866678, published 18th February 1975, see column 4, lines 52-58, Jeter --	1,5

* Special categories of cited documents: [15]

"A" document defining the general state of the art

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
20th December 1979	- 3 JAN. 1980
International Searching Authority [1]	**Signature of Authorized Officer [20]**
European Patent Office	G.L.M. Kruydenberg

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

	US, A, 2000716, published 7th May 1935, see page 2, left-hand column, lines 53-64, Polk	1,5,8
	US, A, 2690934, published 5th October 1954, see column 3, lines 7-58, Holcombe	1,5
	US, A, 3963075, published 15th June 1976, see abstract, Evans	1,4,9
	US, A, 1985229, published 25th December 1934, see page 1, right-hand column, lines 34-40, Allen	1,4,9

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ...., because they relate to subject matter [12] not required to be searched by this Authority, namely:

2. ☐ Claim numbers ...., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.